MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

SUPPLEMENTARY EXAMINATION

TRIMESTER 1, 2015/2016

ETN4086 – MOBILE AND SATELLITE COMMUNICATIONS

(TE, MCE)

19 NOV 2015
2.30 PM – 4.30 PM
(2 HOURS)

INSTRUCTION TO STUDENT

1. This examination paper consists of **9 pages** (including the cover page) with **4 questions only**.

2. Each question is worth **25 marks. Attempt ALL questions.**

3. Please write all your answers in the Answer Booklet provided. **Show all relevant steps** to obtain maximum marks.

4. There is an **appendix** of useful charts, constants and formulae at the end of this question paper.

Question 1

(a) State two (2) advantages and two (2) drawbacks of frequency reuse in cellular network. [4 marks]

(b) In order to further increase the capacity, an engineer has two options to implement: cell splitting and sectoring. Explain how both implementations help to increase the system capacity. If you are the engineer, which one would be your option for a simple and fast deployment? [8 marks]

(c) A telecommunication company has been given a frequency band of 890 MHz – 970 MHz for its full-duplex link using frequency division duplexing (FDD). Each voice channel uses 25kHz of bandwidth. Find the number of channels available per cell if:

(i) the system uses 4-cell reuse. [4 marks]

(ii) the system uses 7-cell reuse. Comment on the capacity per cell with respect to (c)(i) if the cell radius is the same. [2 marks]

(iii) The number of channels per cell in a 120° sectorize antenna is the same as without sectoring it. Hence, how does the total capacity actually increase with sectoring? [3 marks]

(iv) Find the total number of users for the system in (c)(ii) if the system can support 3% blocking with an average call of 6 calls per hour. The average call duration is two minutes. [4 marks]

Question 2

(a) The following questions refer to a mobile network.

Table Q2

Generation	Definition	Throughput / Speed	Technology
1G	Analog	14.4 Kbps (peak)	AMPS,NMT,TACS
2G	Digital Narrow band circuit data	9.6/14.4 Kbps	TDMA,CDMA
2.5G	Packet Data	171.2 Kbps(peak), 20-40 Kbps	GPRS
3G	Digital Broadband Packet Data	3.1 Mbps (peak) 500-700 Kbps	CDMA 2000 (1xRTT, EVDO), UMTS, EDGE
4G	Digital Broadband Packet, All IP, Very high throughput	100-300 Mbps (peak) 3-5 Mbps 100 Mbps (Wi-Fi)	WiMax LTE Wi-Fi

Continued...

(i) State one main feature for each generation of mobile network (i.e. 1G, 2G, 2.5G, 3G and 4G) as seen in Table Q2. [5 marks]

(ii) What are the advantages of packet data as compared to circuit data? [2 marks]

(iii) Explain why the term All IP-based is use in 4G. [2 marks]

(iv) Discuss the function of Home Location Register (HLR) and Visitor Location Register (VLR) in 2G. [4 marks]

(b) Distinguish between large-scale fading and small-scale fading. [4 marks]

(b) Consider a base-station transmitter operating at 900 MHz carrier frequency. For a mobile moving at a speed 72 km/h, calculate the received carrier frequency if the mobile is moving

(i) directly towards the base-station transmitter [4 marks]

(ii) in a direction which is 60 degrees to the direction of arrival of the transmitted signal [3 marks]

(iii) in a direction perpendicular to the direction of arrival of the transmitted signal [1 mark]

Question 3

(a) Draw a system configuration and link of satellite communication.

[5 marks]

(b) The earth rotates once in a sidereal day (23 hours 56 minutes 4.09 seconds), and a geostationary satellite must have exactly the same orbital period. Consider a satellite in a circular orbit in the equatorial plane with a period of 23 hours and 50 minutes. Find

(i) the radius of the satellite orbit.

[4 marks]

(ii) the angular drift of the satellite around its orbit per sidereal day, measured at the earth centre.

[4 marks]

(iii) the direction of the drift-towards the east or towards the west.

[2 marks]

(c) State three (3) advantages and three (3) disadvantages of highly-elliptical orbit satellite.

[6 marks]

Continued...

(d) In a satellite orbit location, given that the elevation angle is 5°, the distance from an earth station is 42164 km, and earth's radius is 6378 km. Determine the nadir angle and latitude angles of the satellite's location using topocentric co-ordinates.

[4 marks]

Question 4

(a) An earth station is receiving a signal from a satellite. With all the parameters given in Table Q4 below, answer the following:

Table Q4

Satellite distance from the center of Earth	26378 km
Transmitting power at satellite antenna, P_T	15 W
Uplink frequency, f_u	6 GHz
Satellite antenna 3 dB beamwidth, θ_{3dB}	2.5°
Downlink frequency, f_d	4 GHz
Earth station antenna type	Parabolic
Earth station antenna diameter	6 m
Antenna efficiency, η	
Satellite antenna	0.60
Earth station antenna	0.65

(i) Calculate the gain of the satellite station's transmitting antenna (in decibel). [2 marks]

(ii) Determine the Effective Isotropic Radiated Power (EIRP) (in decibel) of the transmitted signal. Assume no feeder and branching loss. [2 marks]

(iii) Determine the power flux density at the earth station. [2 marks]

(iv) Calculate the gain of the earth station's receiving antenna (in decibel).

[2 marks]

(v) Calculate the free space loss from the satellite to earth station's receiving antenna. [2 marks]

(vi) Estimate the power received by the earth station's receiver. Assume that only free space loss is incurred. [2 marks]

(b) A Low Noise Amplifier (LNA) is connected to a receiver which has a noise figure of 12 dB. The gain of the LNA is 40 dB, and its noise temperature is 120K. Calculate the overall noise temperature referred to the LNA input.

[4 marks]

Continued...

(c) A telephone company operates an FDM-FM-FDMA satellite system with maximum baseband bandwidth, f_{max} = 360 kHz, and signal-to-noise ratio S/N = 50 dB. Assume the root-mean-square (rms) frequency deviation of the test tone is Δf_{rms} = 300 kHz, multi-channel peak factor g = 3.2 and a pre-emphasis and de-emphasis improvement of P = 4 dB and noise weighting factor, W = 3 dB. The system can accommodate n = 200 telephone channels, each with a channel bandwidth b = 4.5 kHz. Find the following by referring to the appendices if necessary.

(i) Bandwidth of the FM signal, B. [3 marks]

(ii) Carrier-to-noise power ratio, C/N. [2 marks]

(iii) As a result of increasing demand, the company has to accommodate a larger amount of load by increasing the number of channels to n = 300. Due to bandwidth limitation, the company has no choice but to reduce the channel bandwidth to b = 3 kHz. Will this change the B and C/N? Prove your case by re-calculating (c)(i) and (c)(ii). [4 marks]

Continued...

Appendix I: Constant values

Gravitation parameter, μ	=	3.986×10^{14} m^3/s^2
Mean Earth radius, R_E	=	6378 km
Speed of light, c	=	3×10^{8} m/s
Sidereal day	=	23h 56m 4.09s
Boltzmann constant, k	=	1.379×10^{-23} J/K = -228.6 dBW/Hz K

Appendix II: Table of Complementary Error Function

$$erfc(z)=\frac{2}{\sqrt{\pi}}\int_z^{\infty} e^{-t^2}\,dt \quad \text{for } 0\le z\le 3.99 \text{ in steps of } 0.01$$

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	1.000E+00	9.887E-01	9.774E-01	9.662E-01	9.549E-01	9.436E-01	9.324E-01	9.211E-01	9.099E-01	8.987E-01
0.1	8.875E-01	8.764E-01	8.652E-01	8.541E-01	8.431E-01	8.320E-01	8.210E-01	8.100E-01	7.991E-01	7.882E-01
0.2	7.773E-01	7.665E-01	7.557E-01	7.450E-01	7.343E-01	7.237E-01	7.131E-01	7.026E-01	6.921E-01	6.817E-01
0.3	6.714E-01	6.611E-01	6.509E-01	6.407E-01	6.306E-01	6.206E-01	6.107E-01	6.008E-01	5.910E-01	5.813E-01
0.4	5.716E-01	5.620E-01	5.525E-01	5.431E-01	5.338E-01	5.245E-01	5.153E-01	5.063E-01	4.973E-01	4.883E-01
0.5	4.795E-01	4.708E-01	4.621E-01	4.535E-01	4.451E-01	4.367E-01	4.284E-01	4.202E-01	4.121E-01	4.041E-01
0.6	3.961E-01	3.883E-01	3.806E-01	3.730E-01	3.654E-01	3.580E-01	3.506E-01	3.434E-01	3.362E-01	3.292E-01
0.7	3.222E-01	3.153E-01	3.086E-01	3.019E-01	2.953E-01	2.888E-01	2.825E-01	2.762E-01	2.700E-01	2.639E-01
0.8	2.579E-01	2.520E-01	2.462E-01	2.405E-01	2.349E-01	2.293E-01	2.239E-01	2.186E-01	2.133E-01	2.082E-01
0.9	2.031E-01	1.981E-01	1.932E-01	1.884E-01	1.837E-01	1.791E-01	1.746E-01	1.701E-01	1.658E-01	1.615E-01
1.0	1.573E-01	1.532E-01	1.492E-01	1.452E-01	1.414E-01	1.376E-01	1.339E-01	1.302E-01	1.267E-01	1.232E-01
1.1	1.198E-01	1.165E-01	1.132E-01	1.100E-01	1.069E-01	1.039E-01	1.009E-01	9.800E-02	9.516E-02	9.239E-02
1.2	8.969E-02	8.704E-02	8.447E-02	8.195E-02	7.949E-02	7.710E-02	7.476E-02	7.249E-02	7.027E-02	6.810E-02
1.3	6.599E-02	6.394E-02	6.193E-02	5.998E-02	5.809E-02	5.624E-02	5.444E-02	5.269E-02	5.098E-02	4.933E-02
1.4	4.771E-02	4.615E-02	4.462E-02	4.314E-02	4.170E-02	4.030E-02	3.895E-02	3.763E-02	3.635E-02	3.510E-02
1.5	3.389E-02	3.272E-02	3.159E-02	3.048E-02	2.941E-02	2.838E-02	2.737E-02	2.640E-02	2.545E-02	2.454E-02
1.6	2.365E-02	2.279E-02	2.196E-02	2.116E-02	2.038E-02	1.962E-02	1.890E-02	1.819E-02	1.751E-02	1.685E-02
1.7	1.621E-02	1.559E-02	1.500E-02	1.442E-02	1.387E-02	1.333E-02	1.281E-02	1.231E-02	1.183E-02	1.136E-02
1.8	1.091E-02	1.048E-02	1.006E-02	9.653E-03	9.264E-03	8.889E-03	8.528E-03	8.179E-03	7.844E-03	7.521E-03
1.9	7.210E-03	6.910E-03	6.622E-03	6.344E-03	6.077E-03	5.821E-03	5.574E-03	5.336E-03	5.108E-03	4.889E-03
2.0	4.678E-03	4.475E-03	4.281E-03	4.094E-03	3.914E-03	3.742E-03	3.577E-03	3.418E-03	3.266E-03	3.120E-03
2.1	2.979E-03	2.845E-03	2.716E-03	2.593E-03	2.475E-03	2.361E-03	2.253E-03	2.149E-03	2.049E-03	1.954E-03
2.2	1.863E-03	1.776E-03	1.692E-03	1.612E-03	1.536E-03	1.463E-03	1.393E-03	1.326E-03	1.262E-03	1.201E-03
2.3	1.143E-03	1.088E-03	1.034E-03	9.838E-04	9.354E-04	8.893E-04	8.452E-04	8.032E-04	7.631E-04	7.249E-04
2.4	6.885E-04	6.538E-04	6.207E-04	5.892E-04	5.592E-04	5.306E-04	5.034E-04	4.774E-04	4.528E-04	4.293E-04
2.5	4.070E-04	3.857E-04	3.655E-04	3.463E-04	3.280E-04	3.107E-04	2.942E-04	2.785E-04	2.636E-04	2.495E-04
2.6	2.360E-04	2.233E-04	2.112E-04	1.997E-04	1.888E-04	1.785E-04	1.687E-04	1.594E-04	1.506E-04	1.422E-04
2.7	1.343E-04	1.268E-04	1.197E-04	1.130E-04	1.066E-04	1.006E-04	9.492E-05	8.952E-05	8.441E-05	7.958E-05
2.8	7.501E-05	7.069E-05	6.661E-05	6.275E-05	5.910E-05	5.566E-05	5.240E-05	4.933E-05	4.642E-05	4.368E-05
2.9	4.110E-05	3.866E-05	3.635E-05	3.418E-05	3.213E-05	3.020E-05	2.838E-05	2.667E-05	2.505E-05	2.353E-05
3.0	2.209E-05	2.074E-05	1.947E-05	1.827E-05	1.714E-05	1.608E-05	1.508E-05	1.414E-05	1.326E-05	1.243E-05
3.1	1.165E-05	1.092E-05	1.023E-05	9.578E-06	8.970E-06	8.398E-06	7.862E-06	7.358E-06	6.885E-06	6.442E-06
3.2	6.026E-06	5.635E-06	5.269E-06	4.926E-06	4.604E-06	4.303E-06	4.020E-06	3.755E-06	3.507E-06	3.275E-06
3.3	3.058E-06	2.854E-06	2.664E-06	2.485E-06	2.319E-06	2.162E-06	2.017E-06	1.880E-06	1.753E-06	1.633E-06
3.4	1.522E-06	1.418E-06	1.321E-06	1.230E-06	1.145E-06	1.066E-06	9.922E-07	9.233E-07	8.590E-07	7.990E-07
3.5	7.431E-07	6.910E-07	6.423E-07	5.970E-07	5.548E-07	5.155E-07	4.788E-07	4.447E-07	4.130E-07	3.834E-07
3.6	3.559E-07	3.303E-07	3.064E-07	2.843E-07	2.636E-07	2.445E-07	2.267E-07	2.101E-07	1.947E-07	1.804E-07
3.7	1.672E-07	1.548E-07	1.434E-07	1.327E-07	1.229E-07	1.137E-07	1.052E-07	9.736E-08	9.005E-08	8.328E-08
3.8	7.700E-08	7.119E-08	6.579E-08	6.080E-08	5.617E-08	5.189E-08	4.792E-08	4.425E-08	4.085E-08	3.770E-08
3.9	3.479E-08	3.210E-08	2.961E-08	2.731E-08	2.518E-08	2.322E-08	2.140E-08	1.972E-08	1.817E-08	1.674E-08

Note: 1.000E-01 = 1.000×10^{-1}

For $z>4$, $\quad erfc(z)\approx\frac{1}{\sqrt{\pi}}\left(\frac{e^{-z^2}}{z}\right)$

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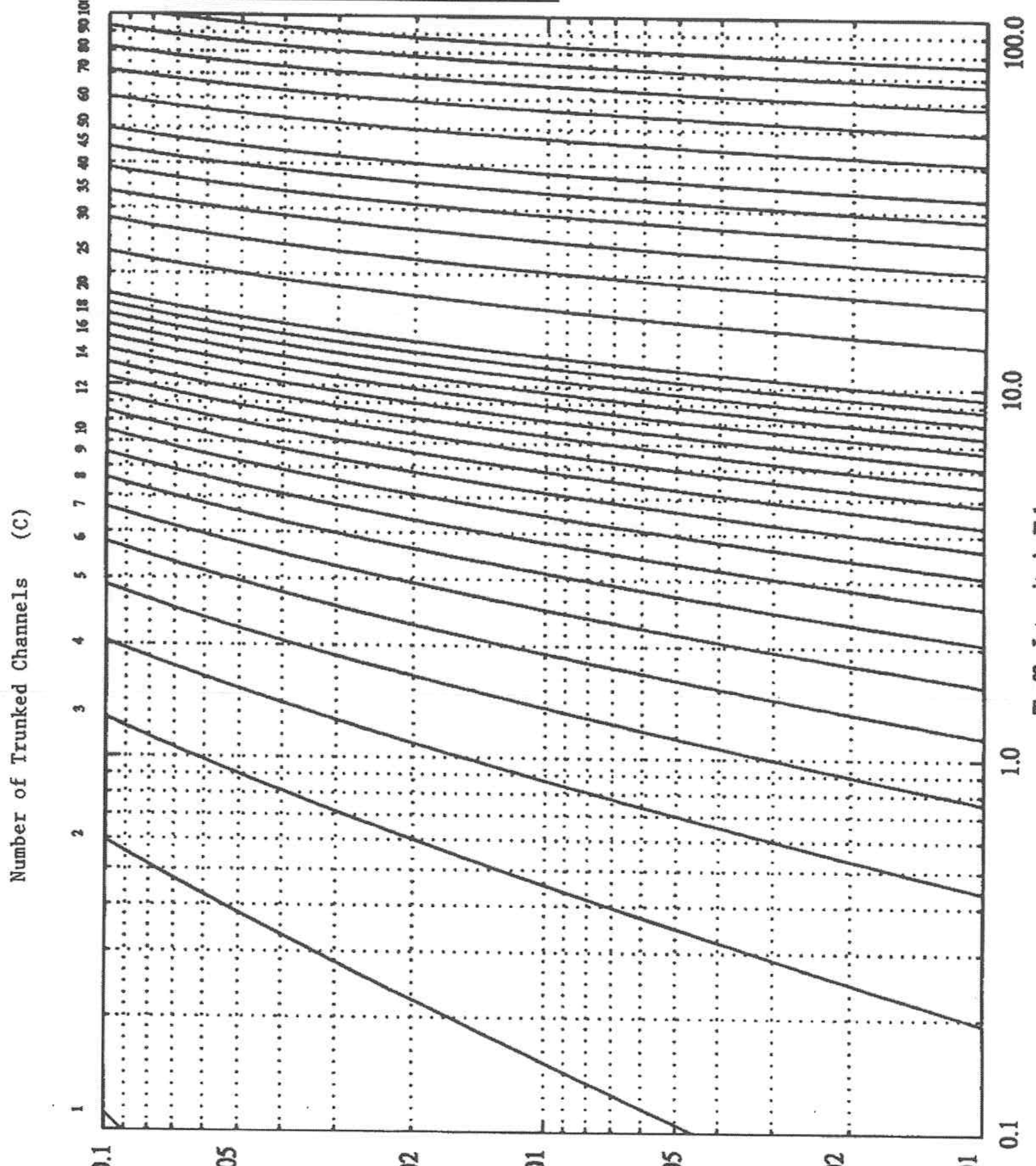
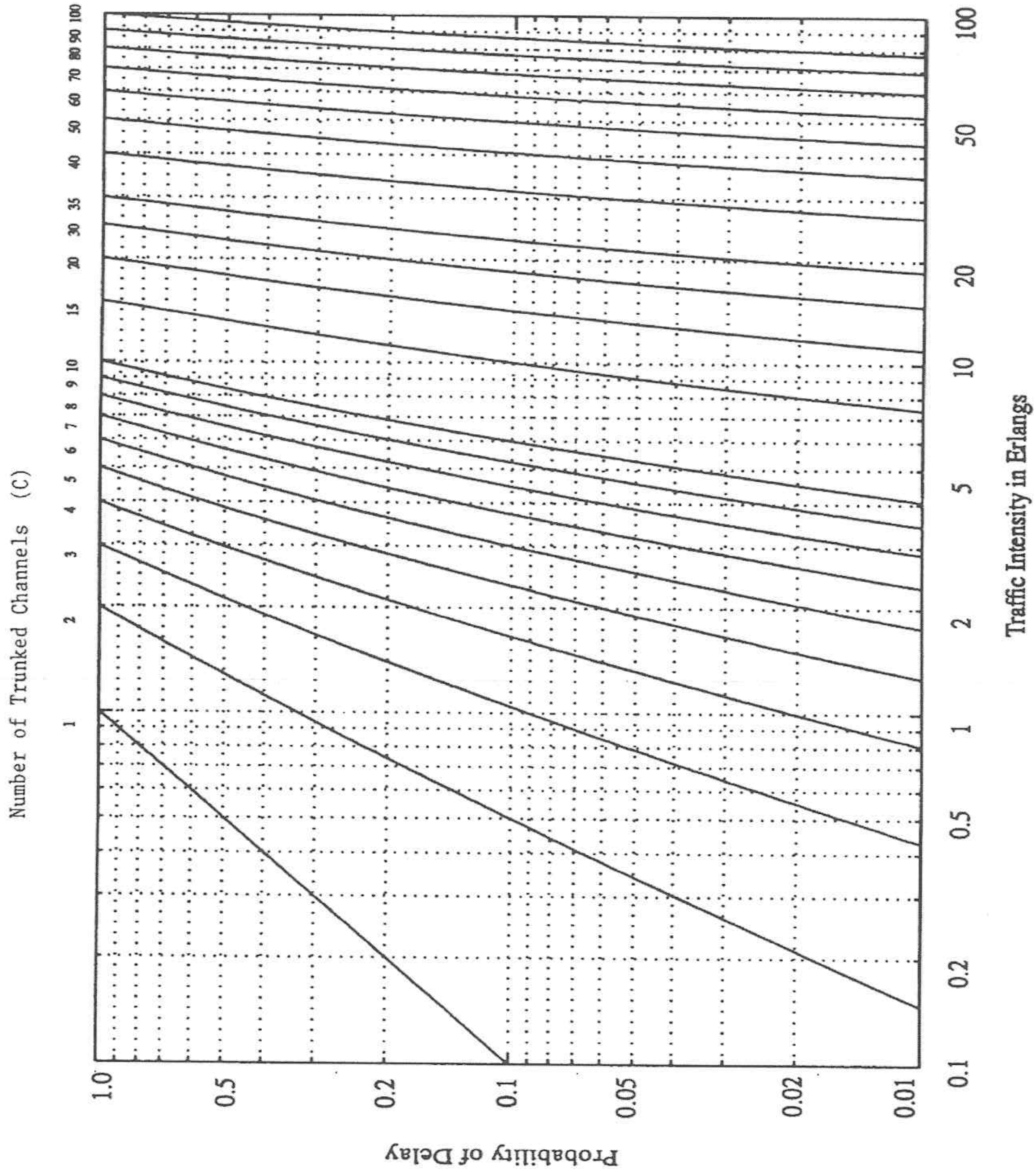
Appendix III: Erlang B and Erlang C Chart



The Erlang B chart showing the probability of blockings as functions of the number of channels and traffic intensity in Erlangs.



The Erlang C chart showing the probability of a call being delayed as a function of the number of channels and traffic intensity in Erlangs.

Appendix IV: Formulae

Remarks: The general formulae below may need to be modified according to the context.

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Antenna

Effective isotropic radiated power, $EIRP = P_t G_t$

Power flux density, $\phi = \dfrac{EIRP}{4\pi R^2}$

Received power, $P_r = \phi A_{eff}$

Antenna gain of a circular aperture or reflector of diameter D:

$$G_{\max} = \left(\frac{4\pi}{\lambda^2}\right) A_{eff} = \eta\left(\frac{\pi D}{\lambda}\right)^2 = \eta\left(\frac{70\pi}{\theta_{3dB}}\right)^2, \text{ where } \theta_{3dB} = 70\left(\frac{\lambda}{D}\right)$$

Link Analysis

Received power, $[P_r] = [EIRP] + [G_r] - [L_{Total}]$

Free space loss,

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$$

$$PL(\mathrm{dB}) = 10\log\left(\frac{P_t}{P_r}\right) = -10\log\left(\frac{\lambda^2}{(4\pi)^2 d^2}\right)$$

$$P_r(d)\,\mathrm{dBm} = 10\log\left[\frac{P_r(d_0)}{0.001\,\mathrm{W}}\right] + 20\log\left(\frac{d_0}{d}\right) \qquad d \ge d_0 \ge d_f$$

Log-Distance Path Loss

$$\overline{PL}(\mathrm{dB}) = \overline{PL}(d_0) + 10\,n\,\log\left(\frac{d}{d_0}\right)$$

Doppler shift,

$$f_d = \frac{v}{\lambda}\cos\theta$$

Noise power spectral density, $N_o = kT$

Noise factor, $F = 1 + \dfrac{T_e}{T_o}$

System noise temperature with reference to the antenna output,

$$T_S = T_{ant} + T_{e1} + \frac{T_{e2}}{G_1} + \frac{T_{e3}}{G_1 G_2} + \ldots + \frac{T_{en}}{G_1 G_2 \ldots G_{n-1}}$$

FDM-FM-FDMA Satellite System

Signal bandwidth, $B = 2(gl\Delta f_{rms} + f_{max})$

$$\text{where } \log_{10} l = \begin{cases} (-1 + 4\log_{10} n)/20, & n \le 240 \\ (-15 + 10\log_{10} n)/20, & n > 240 \end{cases}$$

Relationship between C/N and S/N is given by:

$$\frac{C}{N} = \left(\frac{S}{N}\right)\left(\frac{b}{B}\right)\left(\frac{f_{\max}}{\Delta f_{rms}}\right)^2 \frac{1}{pw}$$

End of Paper